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LAMONT GEOLOGICAL OBSERVATORY
PALISADES, NEW YORK

SUB-BOTTOM DEPTH RECORDER

by
Bernard Luskin, Archie C. Roberts and Walter C. Beckman

Technical Report No. 16
CU-44-58 NObsr 64547 Geol.

February 1958

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CONTENTS

I INTRODUCTION

This report describes an instrument developed at the Lamont Geological Observatory which is capable of providing continuous soundings of sub-bottom strata at considerable depths. The sound energy source is an electrical spark discharge in water. An intense spark discharge, confined to a very small volume of water, will vaporize the water and produce high-pressure bubbles whose expansion and contraction radiate acoustic energy much like a conventional explosive source. The spectrum of the radiated energy is very broad and a substantial portion of it is included in the low frequency band below 5000 cycles per second. The Sub-bottom Depth Recorder described here has utilized the low frequency energy output of a spark discharge source to obtain continuous records of bedrock lying below more than 450 feet of sediment and 50 feet of water.

The capabilities of a spark discharge as a source of acoustic energy have been used by various investigators for some time. In 1951, Anderson,[1, 2] at the Marine Physical Laboratory of the Scripps Institution of Oceanography constructed a spark discharge source for detailed studies of the deep scattering layer. The Woods Hole Oceanographic Institution has used a spark discharge source for several years in acoustic propagation studies and recently for sub-bottom penetration recording.[3, 4] The functional design of the spark discharge sources of these two equipments is identical with that used in the Sub-bottom Depth Recorder. A more simplified spark discharge source has been used for seismic model studies by Press and Oliver,[5] and Hall,[6] among others. In all these studies, the ease of repetitive generation, the wide-band spectrum and impulsive character of a spark discharge source have proved advantageous. In sub-bottom recording for geophysical studies, the substantial low frequency content of the spark discharge source has proven to be especially useful. Over 500 miles of track have been made in Long Island Sound using the Sub-bottom Depth Recorder aboard the Research Vessels VEMA and JOSEPH GOLDBERGER. The data obtained make possible the detailed mapping of the bedrock structure beneath the Sound.[7]

II GENERAL DESCRIPTION

The Sub-bottom Depth Recorder (SDR) equipment is contained in three major assemblies: Transmitter Rack, Recording Rack, and Float Assembly. These units are shown in Figures 1, 2 and 3. A block diagram of the system is shown in Figure 4.

The Transmitter Rack contains (top to bottom) a Pulse Trigger Chassis, a 10 kilovolt, 50 milliampere Power Supply, an AC Distribution Chassis, and an electronic Power Supply.

The Recording Rack contains the Recorder, a Control Chassis, a Pre-amplifier and Variable Filter.

The Float Assembly is towed astern by means of the Hydrophone and Electrode cables (types MCOS-4 and RG8/U respectively). The Hydrophone is housed within the Float structure and the Electrode trails slightly astern of the Float.

The SDR equipment is extremely compact and adaptable to rapid installation on a small boat. The two rack assemblies require only 36 inches of panel space each in a standard 19-inch relay rack. The cable is carried in a wooden box with the Float resting atop the box. The entire equipment weighs about 500 pounds but the unit-assembly character of the construction allows the load to be broken down into convenient one or two-man loads. During development trial runs, the equipment was loaded and unloaded several times aboard the T-boat of the Hudson Laboratories. A complete installation, ready for operation, usually took four men less than

20 minutes. Unloading took about 14 minutes. The installation of the SDR aboard the Lamont Geological Observatory's Research Vessel JOSEPH GOLDBERGER is shown in Figure 5.

Aboard the Research Vessel Vema, the installation of the SDR is somewhat different. A hull-mounted transducer is used in place of the towed hydrophone for detecting the signal. The Electrode is towed just off the stern of the ship and no Float Assembly is required. The recorder used is the Precision Depth Recorder Mark V[8] which contains most of the circuits of the Control Chassis so that this unit is also not required. The high voltage spark discharge circuitry, the filtering, and the preamplification units are similar to those of the small-boat equipment.

The equipment requires 1500 watts of 115 volt, 60 cycle-per-second power. Because of the poor regulation characteristics of usual small-boat AC supplies, the equipment has been designed to operate under conditions of voltage fluctuation from 90 to 130 volts and frequency variation from 50 to 70 cps.

III TRANSMITTER RACK

The four units in the Transmitter Rack perform the functions of generating, distributing and monitoring the various power supplies required in the SDR equipment.

The bottom unit (Figure 1) is a LAMBDA regulated power supply, Model C-282M, which supplies B power at 400 volts and filament power at 6.3 VAC to all the electronic circuits in the Control Chassis. Two meters provide continuous monitoring of the voltage and current output of the supply.

The AC Distribution Chassis is a junction box used for distributing the ship's 115 volt, 60 cycle power to the other units. An AC voltmeter and frequency meter provide means of continuously monitoring the ship's generator output. Receptacles are provided on the front panel for plugging in service and test equipment.

The 10 kilovolt, 50 milliampere unit supplies power to the Pulse Trigger Chassis directly above it. The unit contains provision for monitoring the voltage and current output and for varying the magnitude of the output voltage. In addition, the unit has both current and voltage overload protection, a safety interlock and provision for positively discharging the supply immediately when the power is interrupted. A commercial unit was deliberately chosen for use with the SDR equipment because of the safety features normally included. It is particularly hazardous to operate a high voltage equipment in a marine environment aboard a small boat.

Generally, the operating procedures used in handling the cables and Float Assembly are the same as those used in handling live charges in ordinary seismic refraction work at sea. Several commercial equipments are available which provide the required power output and include the necessary safety features. The power supply used in the SDR is a BETA Electric Co. Model 1010-50R.

The Pulse Trigger Chassis is shown in Figure 6 and the circuit diagram of the unit is shown in Figure 7. Ten kilovolt DC power enters the unit and charges the 1 MFD. capacitor through charging resistor R1. C1 is connected to the towed Electrode through the Spark Gap Switch and the RG8/U cable. Spark Gap Switch conduction is initiated by means of a 'tickler' electrode between the main switch electrodes. The 'tickler' pulse is supplied by the secondary of a standard automobile ignition coil through isolation resistor R2. The primary of the ignition coil is in the trigger circuit in the Control Chassis. The trigger circuit diagram is shown in Figure 8. The Spark Gap Switch is shown in Figure 9. R3 provides a bleeder path for the discharge of the cable.

IV RECORDING RACK

The four units in the Recording Rack perform the main function of filtering, amplifying and making a permanent record of the acoustic signals received on the Hydrophone. The bottom unit (Figure 2) is an Allison Model 2-BR filter with individually variable high- and low-pass cutoff frequency controls over the band 60 to 20,000 cps. This unit receives the hydrophone signal and passes the filtered output to the Pre-amplifier unit above it. The Pre-amplifier is a four-stage transistorized amplifier whose circuit diagram is shown in Figure 10. The output of the Pre-amplifier is fed to a Print Circuit (Figure 11) in the Control Chassis. The Print Circuit provides the necessary signal power to the recording styli.

The Control Chassis, just beneath the Recorder, contains the circuitry to provide several auxiliary functions of the Recording Rack. Precision frequencies of 600 cps and 60 cps are generated, amplified and used to drive the sweep and feed motors of the Recorder respectively. The basic frequency standard is a tuning-fork-controlled oscillator circuit whose stability, under ordinary operating conditions, exceeds one part per million. The Trigger Circuit (Figure 8) is included in the Control Chassis as well as a relay circuit operating on the generated precision 60 cycle voltage which insures that the Print Circuit is active only when the Recorder is in full operation.

The Recorder (Figure 12) is an experimental facsimile machine loaned to the Observatory by the Times Facsimile Corporation for use in the Long Island Sound work. The recording process is the same as that used for many years in Precision Depth Recorders at sea.[8, 9, 10] A dry, electrosensitive recording paper is used whose white top coating is burned away by an electrical discharge between styli sweeping across the surface of the paper and the frame of the machine. The black coating underneath the topcoat is thus revealed and forms the permanent record against a white background supplied by the bottom (third) layer of the recording paper.

The driving system consists of a 60-pole phonic-wheel synchronous motor, directly geared to and driving a synchronous arm. The synchronous arm engages and drives successively each of four styli assemblies, mounted on a band supported on the two pulleys at the front of the machine. The sync motor is powered from the precision frequency source in the Control Chassis so that timing errors are essentially non-existent. Furthermore, the spurious, natural-looking features of sounding records usually caused by variations of the ship's power supply frequency are eliminated.

The drive system of the Recorder also generates precision 60 cycle voltage by rotating a steel armature past a stator coil with a permanent-magnet core. This voltage is amplified in the Control Chassis and used to power a small hysteresis-type synchronous motor which drives the paper feed rollers. The 60-cycle voltage thus generated is also used to operate a relay circuit in the Control Chassis which activates the Print

Circuit. This prevents the styli from printing a hole through the paper since the activating relay can only close when the scan and sweep motors are both running.

The feed motor shaft, rotating at one RPM, also operates a switch which produces one minute time marks on the recording by interrupting the Print Circuit input for 3 scans every minute.

The Recorder scan speed is easily changed merely by changing the driving frequency. Various scanning rates from 12 scans/second to 1 scan/second were tried. The most satisfactory speed for the Long Island Sound work was finally set at 4 scans/second which corresponds to a full scale value of 600 feet on the record at the standard sounding velocity of 4800 feet/second.

The feed rate of the paper is 6 cms/minute. At 5 knots, the usual towing speed during operation of the SDR, the vertical exaggeration is approximately 1/3.

Four typical SDR records made in the Hudson River and Long Island Sound are shown in Figures 13-16.

V FLOAT ASSEMBLY

The Float Assembly (Figure 3) is a wooden hull structure suitably streamlined and keel-loaded to provide smooth towing characteristics at speeds up to 8 knots.

The Electrode Assembly (Figure 17) is towed slightly astern of the float. The Electrode itself is an inch-long piece of stainless steel wire pressed into a piece of nylon rod. The life of the Electrode, when pulsed at 4 times per second, varies between 4 and 8 hours. Normally, only the Electrode proper is replaced; however, the entire Electrode Assembly is connected to the cable through the quick-disconnect fitting to minimize downtime in case of failure during an operation.

The Hydrophone is housed in the rubber-covered compartment at the forward end of the Float. It is a magnetostrictive, low-impedance transducer manufactured by the Harris Transducer Company (Model MP-510C). A composite frequency response of the Hydrophone and Pre-amplifier is shown in Figure 18. This response curve is, of course, modified by the filter setting which is operated to give best results in a given area.

Note that a lower limit to the usable frequency range is set by the resolution of the recording. The recording of lower and lower frequencies will reach a point where the length of a one-cycle recording will equal the distance between different reflecting horizons. For example, one cycle of 250 cycles would have a recorded length equivalent to about 10 feet of depth.

VI SUMMARY

The Sub-bottom Depth Recorder is a compact seismic equipment which is capable of providing continuous soundings of sub-bottom strata. An outstanding feature of the equipment is its portability and ease of installation and operation on small boats. The use of an electrical spark discharge as a sound source provides many advantages over the use of conventional explosives: ease of control, ease of repeatability, safety, low cost. The impulsive nature and wide-band spectrum of the spark source is similar to conventional explosion characteristics and the lower power level is overcome to a large degree by the integrated nature of the recording.

The SDR has been used successfully for sub-bottom topographic mapping, deep scattering layer analysis and acoustic propagation studies. The range of penetration through sediments in shallow-water covered areas indicates a wide application for the SDR in foundation studies for bridges, tunnels, causeways and similar structures. The SDR should also prove useful in providing guidance and correlation information for coring operations at sea.

VII ACKNOWLEDGMENTS

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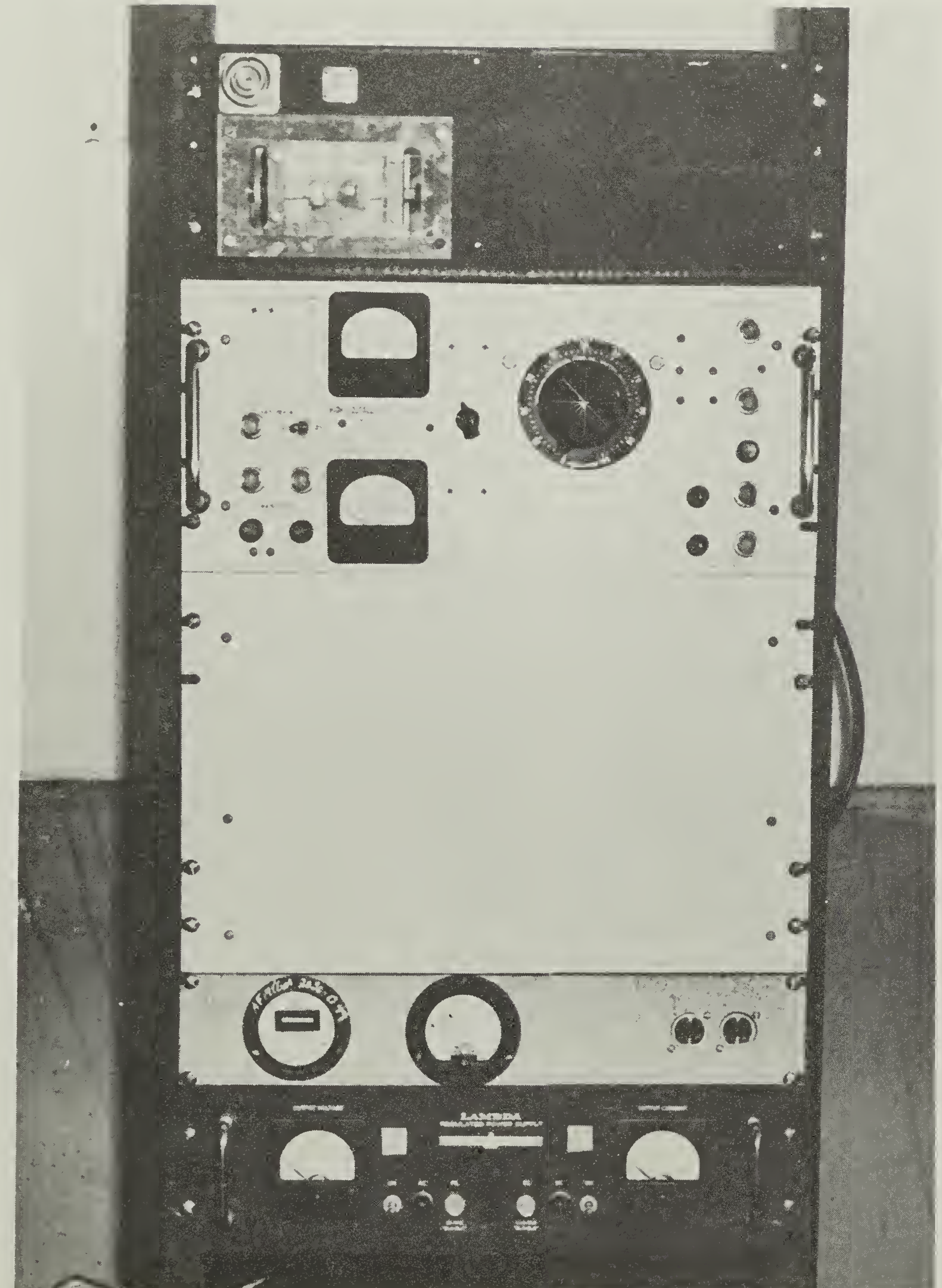


FIGURE 1 TRANSMITTER RACK

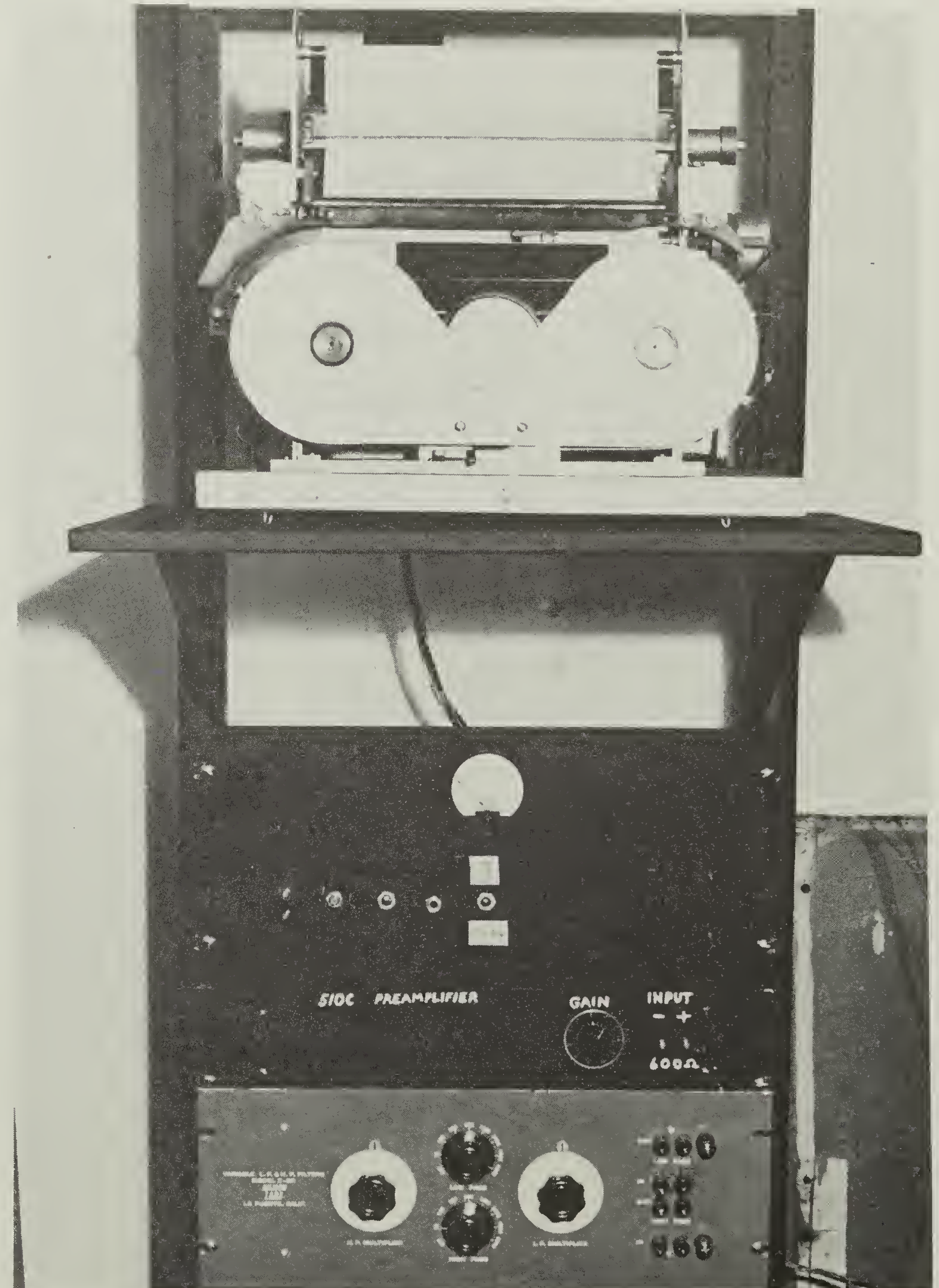


FIGURE 2 RECORDER RACK

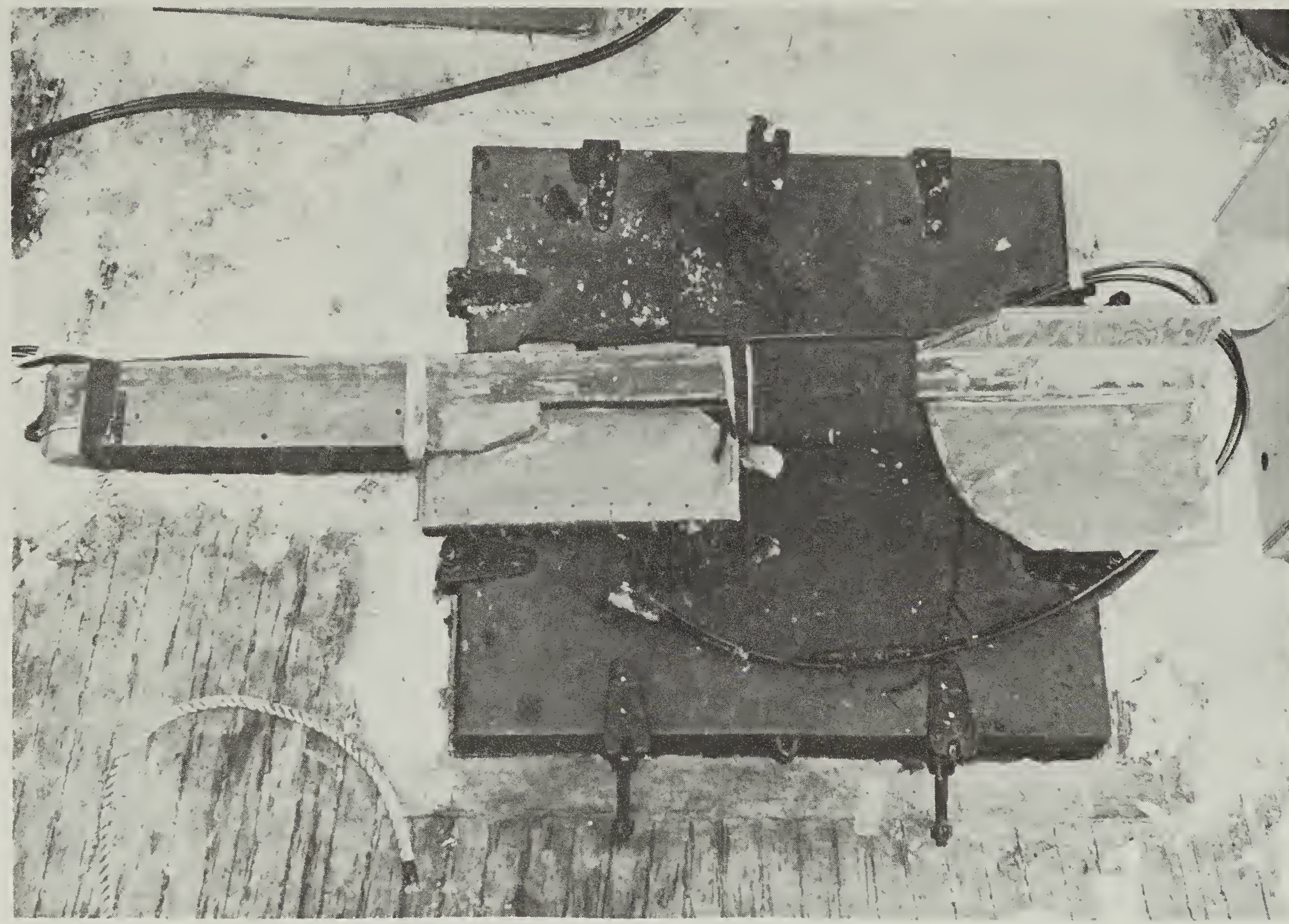


FIGURE 3 SDR FLOAT ASSEMBLY

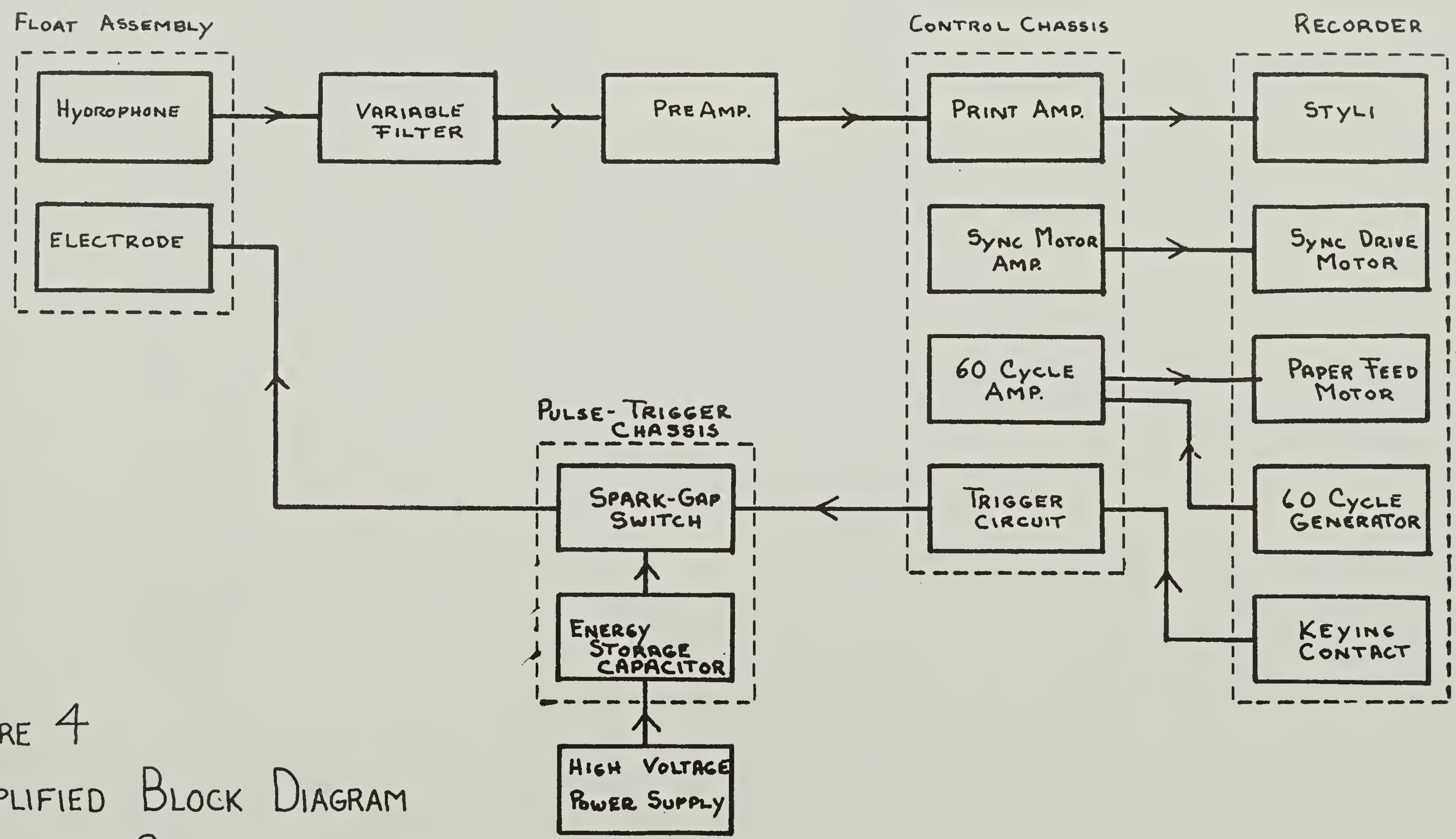


Figure 4
Simplified Block Diagram
Of
SDR
Sub-Bottom Depth Recorder

FIGURE 5 SDR INSTALLATION ABOARD R/V JOSEPH GOLDBERGER

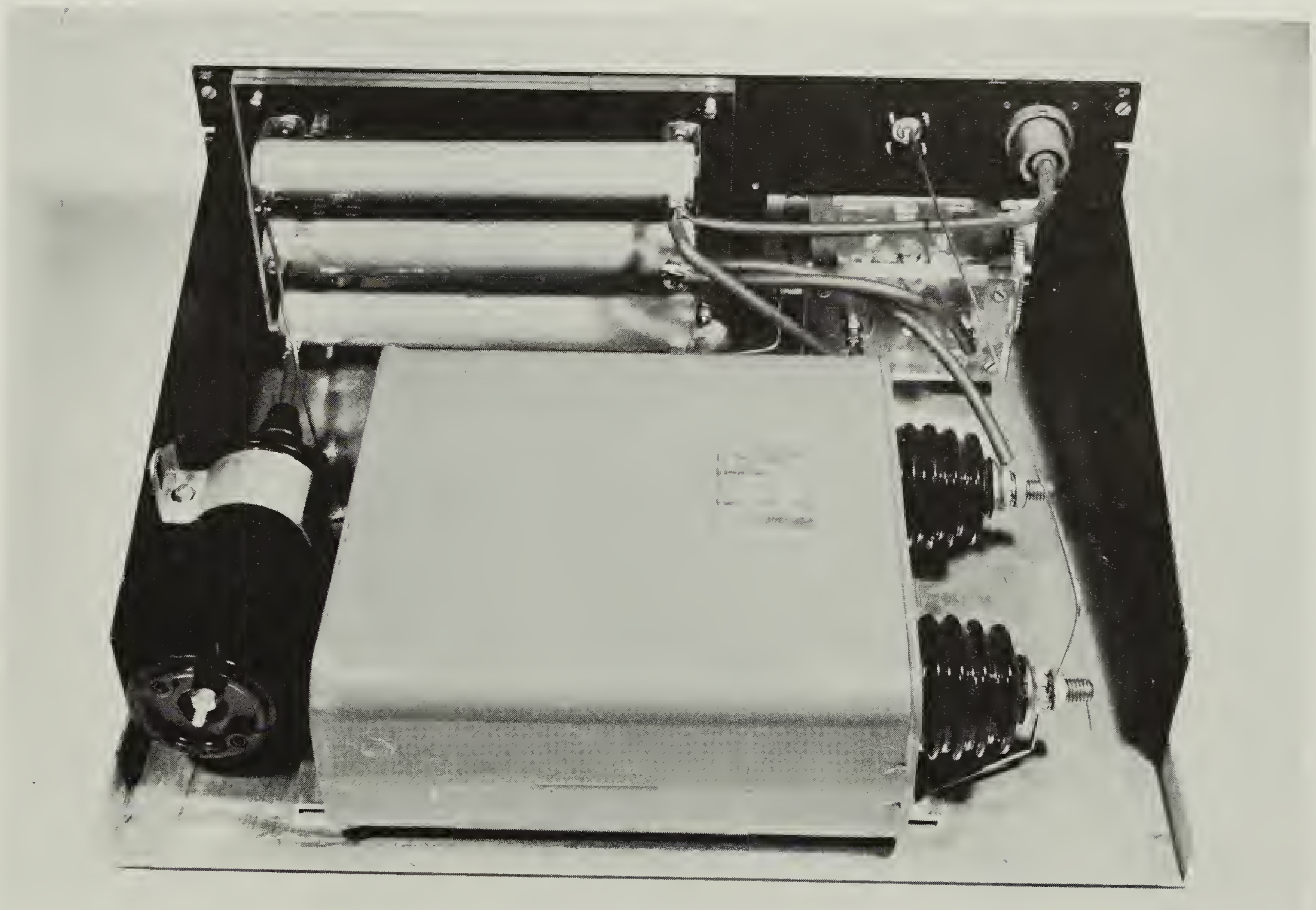


FIGURE 6 SDR PULSE-TRIGGER CHASSIS

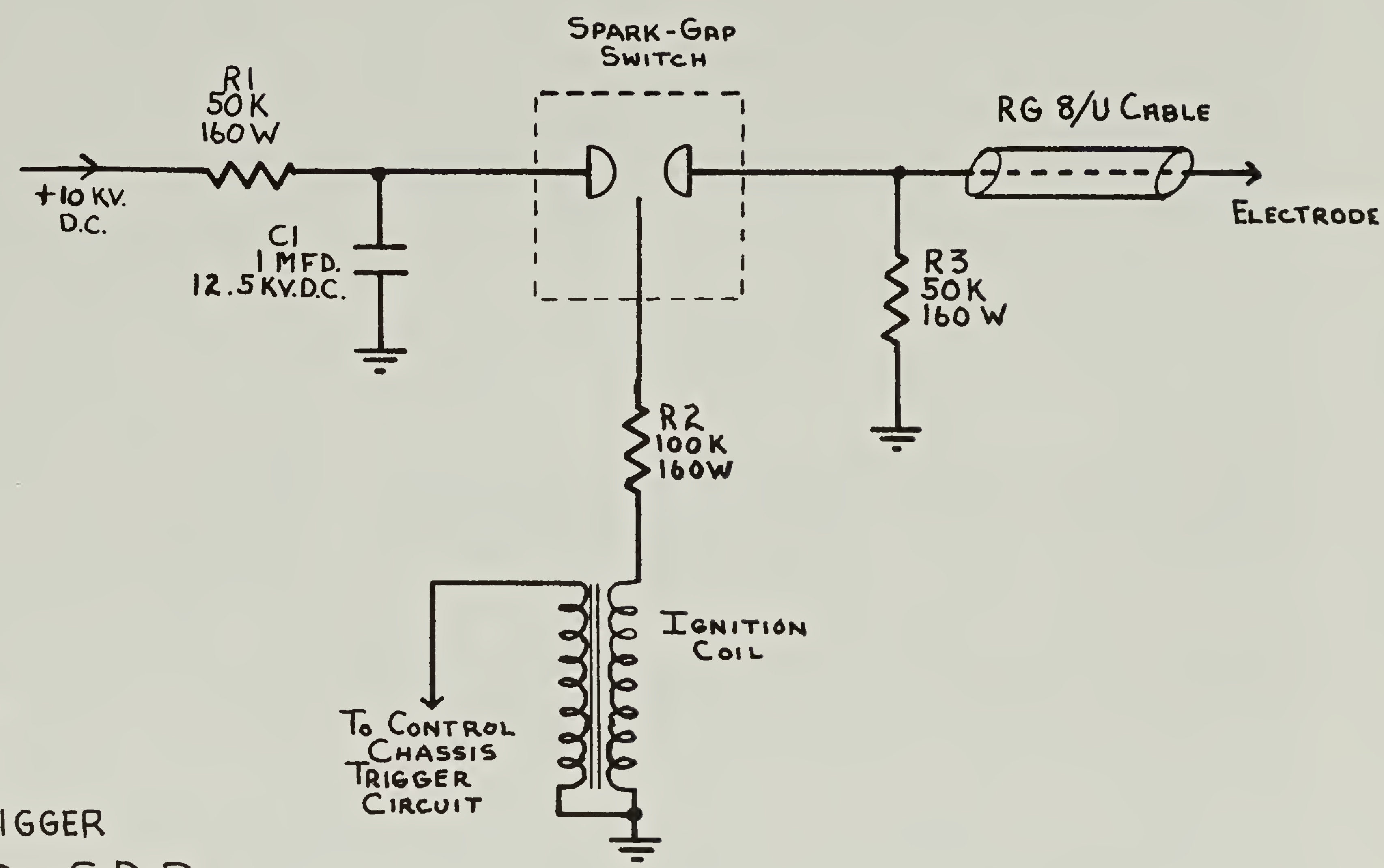
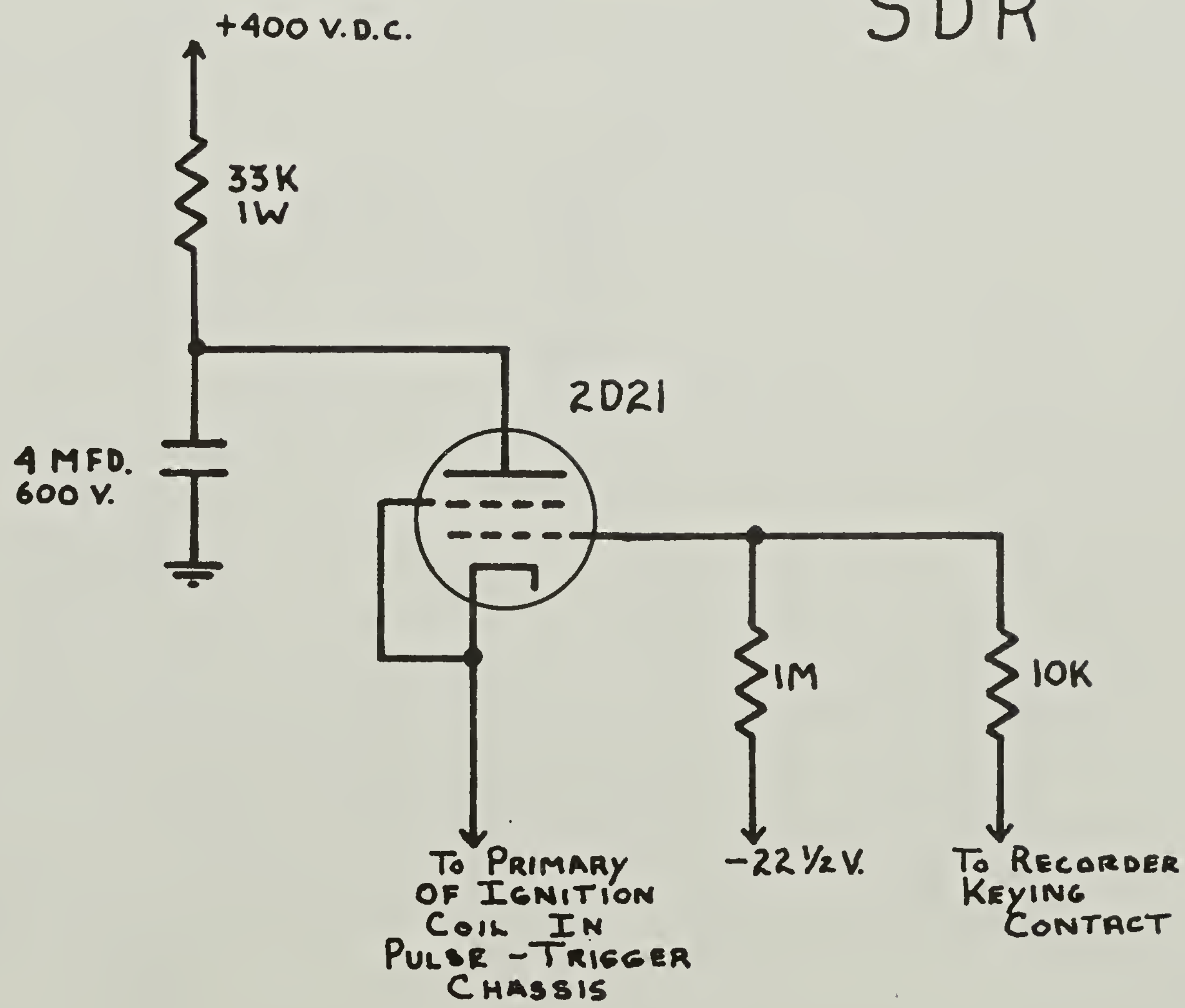


Figure 7
Pulse - Trigger
Chassis Of SDR

Figure 8
Trigger Circuit Of
SDR



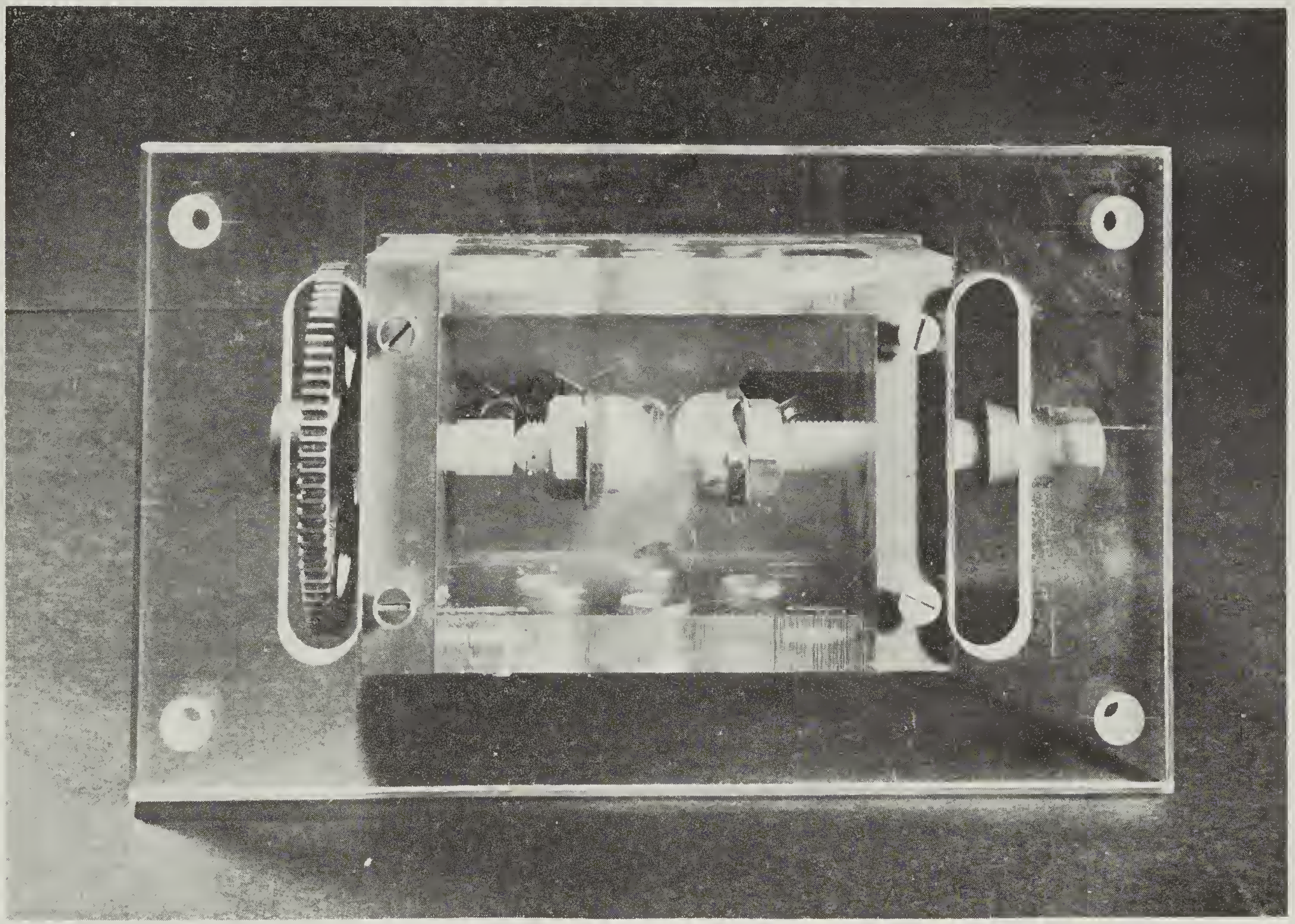


FIGURE 9 SDR SPARK-GAP SWITCH

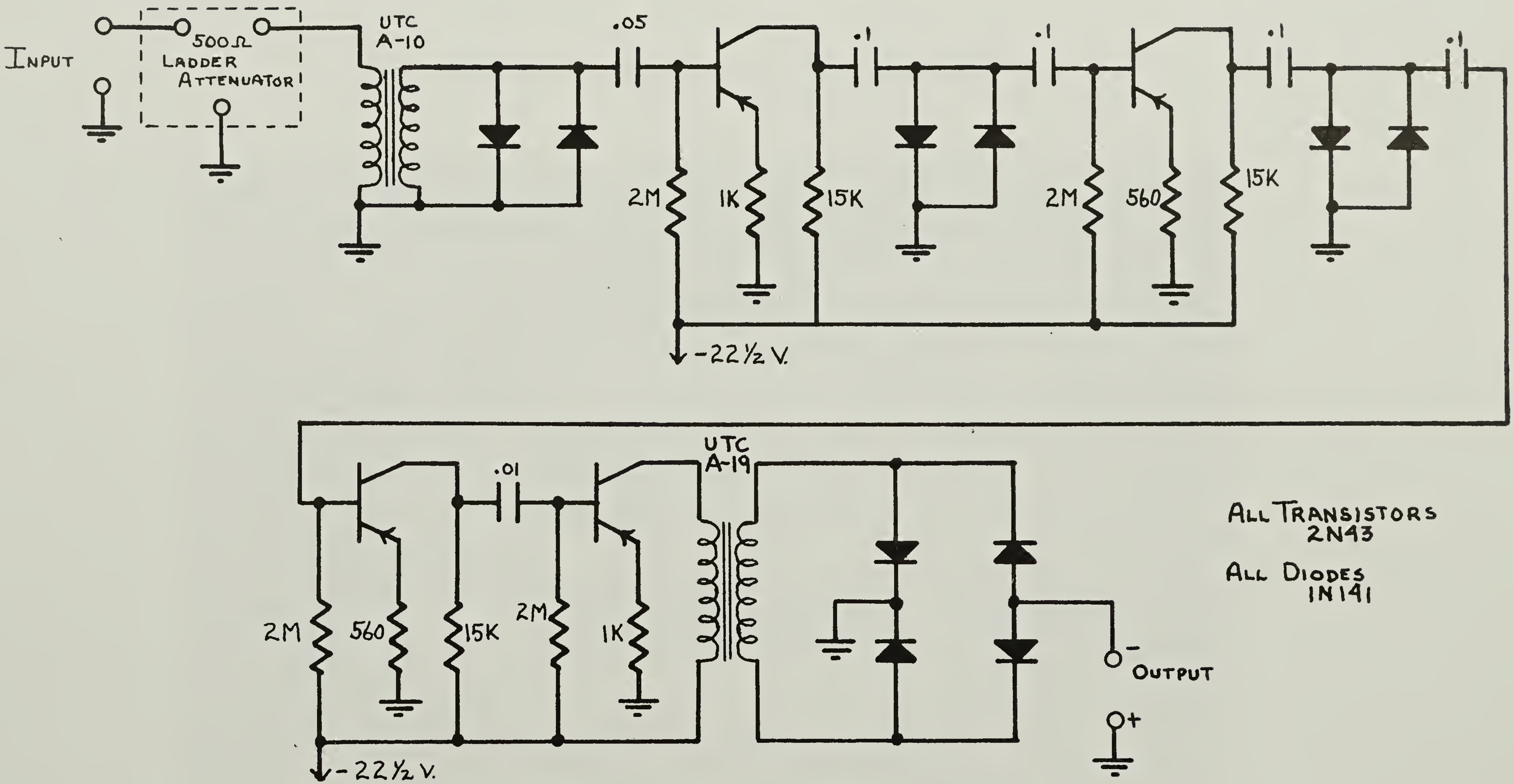


Figure 10
SDR Pre-Amplifier

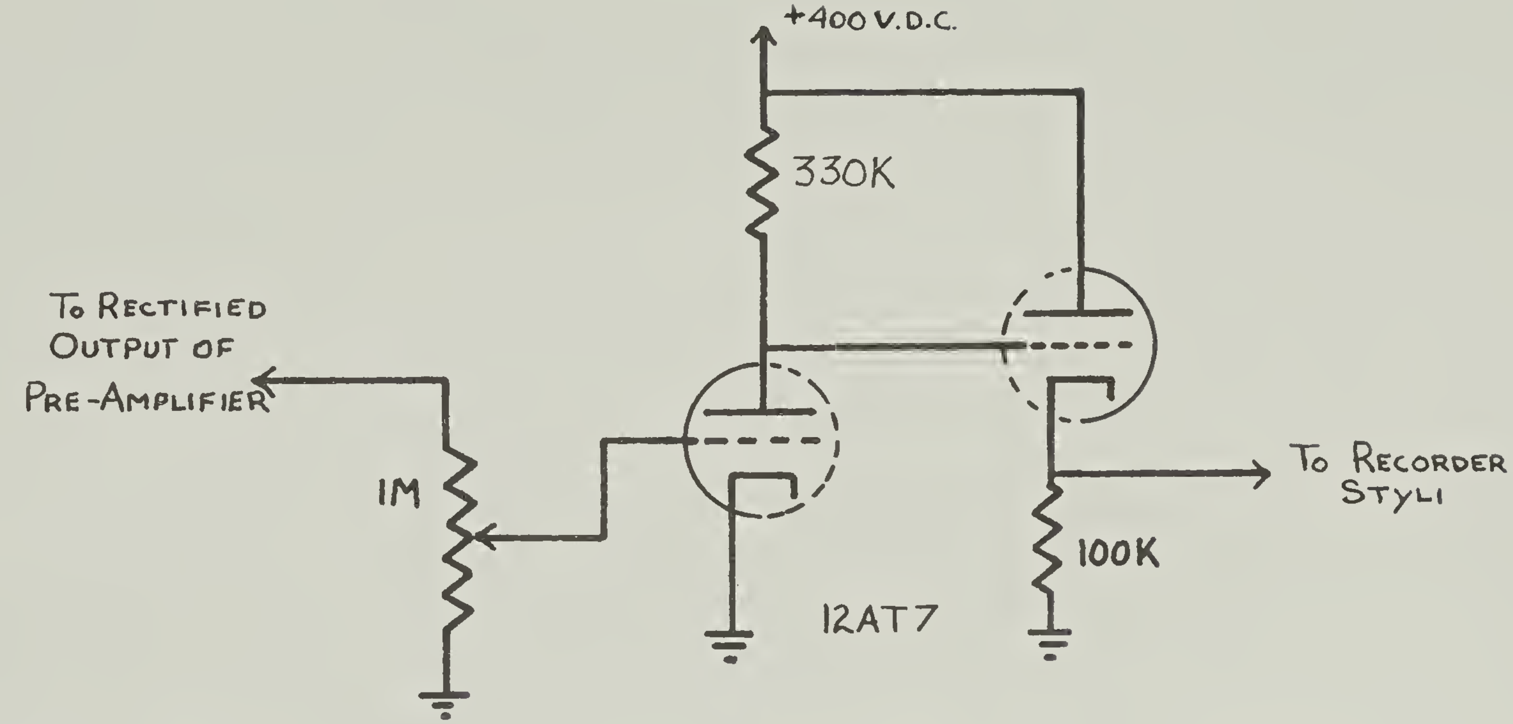


Figure 11
SDR Print Circuit
(Simplified)

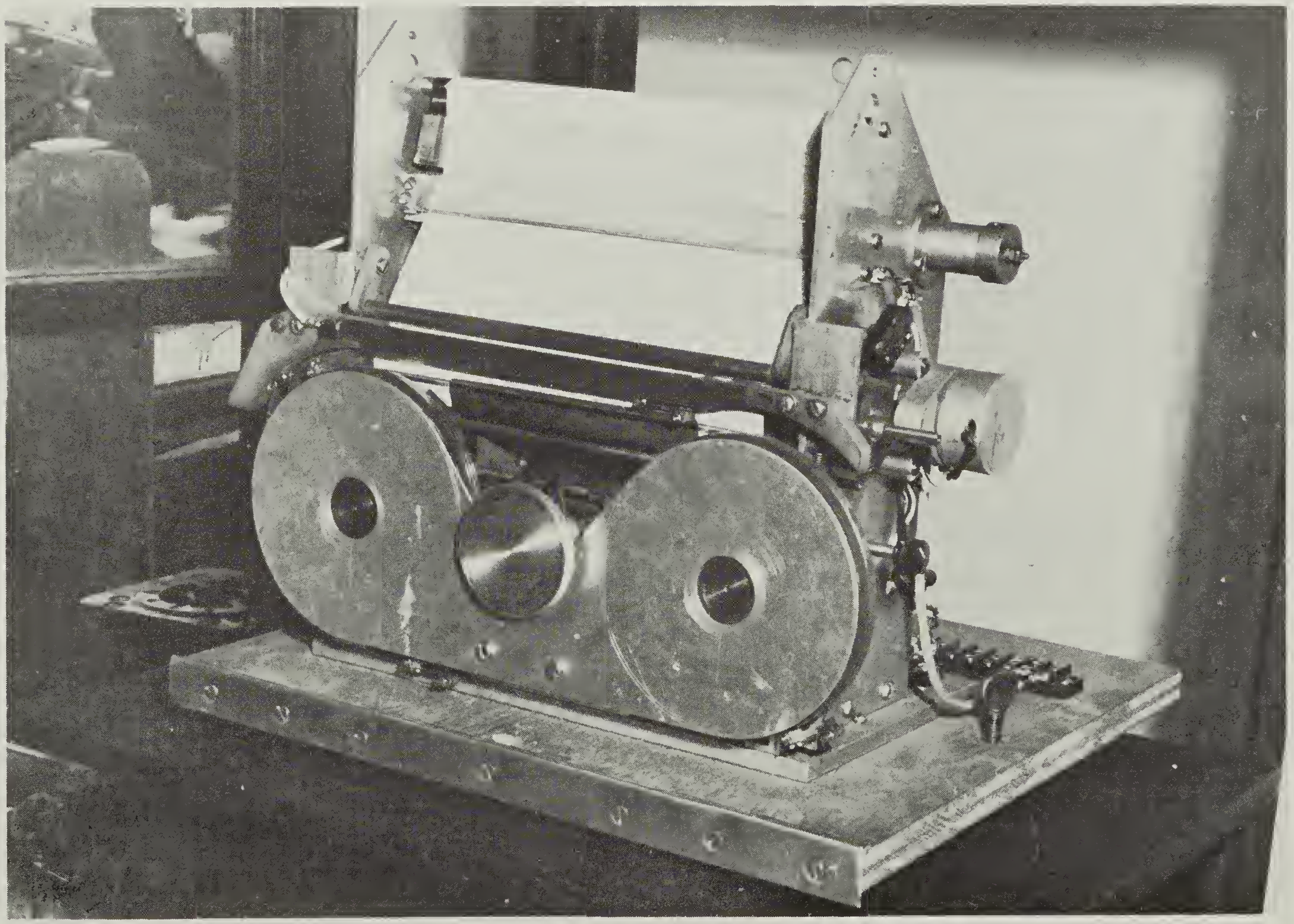


FIGURE 12 SDR RECORDER

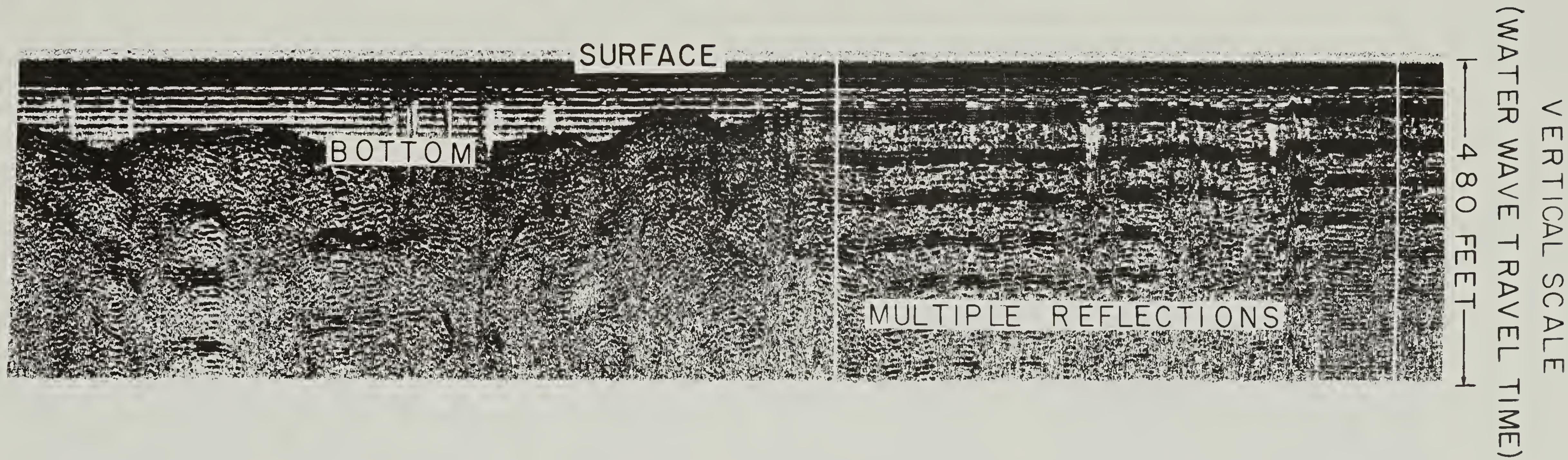


FIGURE 13 EAST RIVER NEAR QUEENS MIDTOWN TUNNEL

This record exhibits the type of record which is obtained in an area where the bottom has high reflectivity. In this case Fordham Gneiss forms the river-bed and is not covered by silt or sedimentary layers.

The many multiple reflections result from the sound reflecting between the water surface and hard river bottom. Multiple reflections of this type will occur also in sedimentary areas if the upper layers are good reflectors. The result is to prevent penetration of the sound to observe deeper layers.

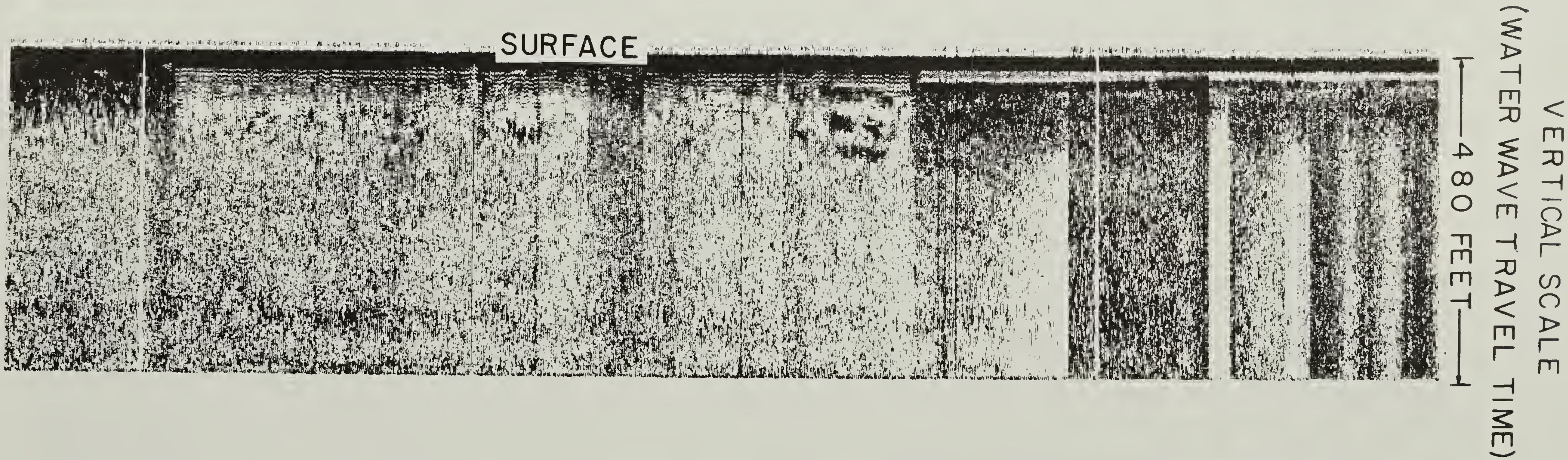


FIGURE 14 HUDSON RIVER NEAR NYACK, NEW YORK

This record exhibits the type of record which is obtained in an area where the bottom has high absorbtion. In this case a silt loaded with gas from organic decay forms the river bed. This silt has a sound velocity of about 1350 feet per second, which is extremely low and a very poor conductor of sound.

Silt layers of this type essentially "blot" the sound and permit no sound penetration through to the deeper layers.

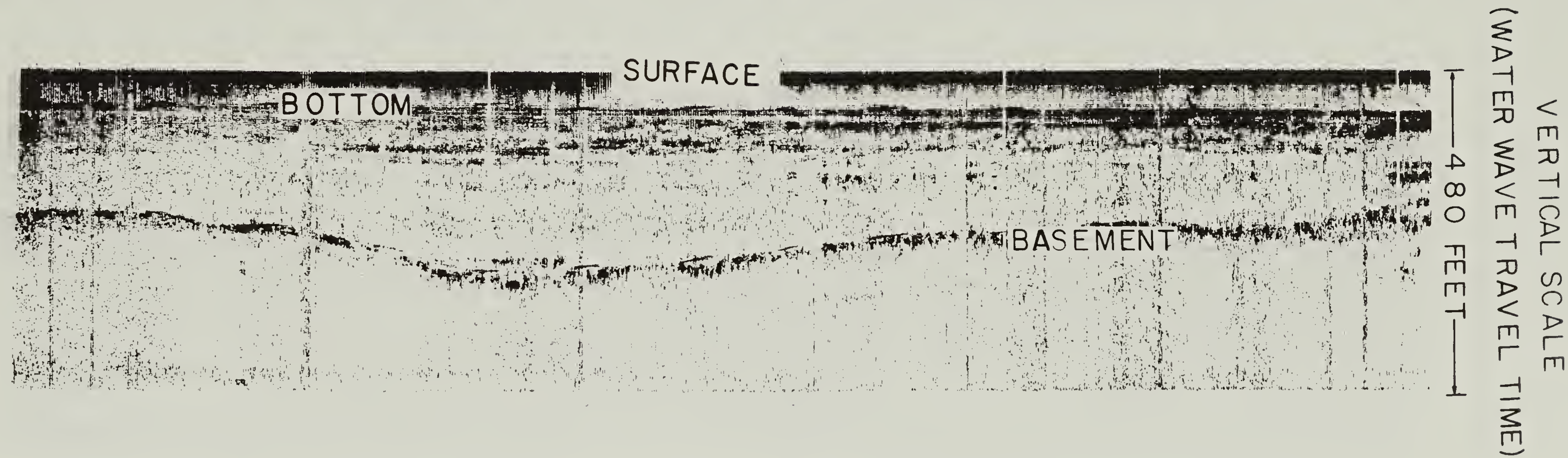


FIGURE 15 LONG ISLAND SOUND NEAR SMITHTOWN BAY, L.I.

This record shows good penetration of the sound energy to basement rock. The rock forms a good reflector and is easily defined. The depth of the basement is about 460 feet, the water depth about 60 feet.

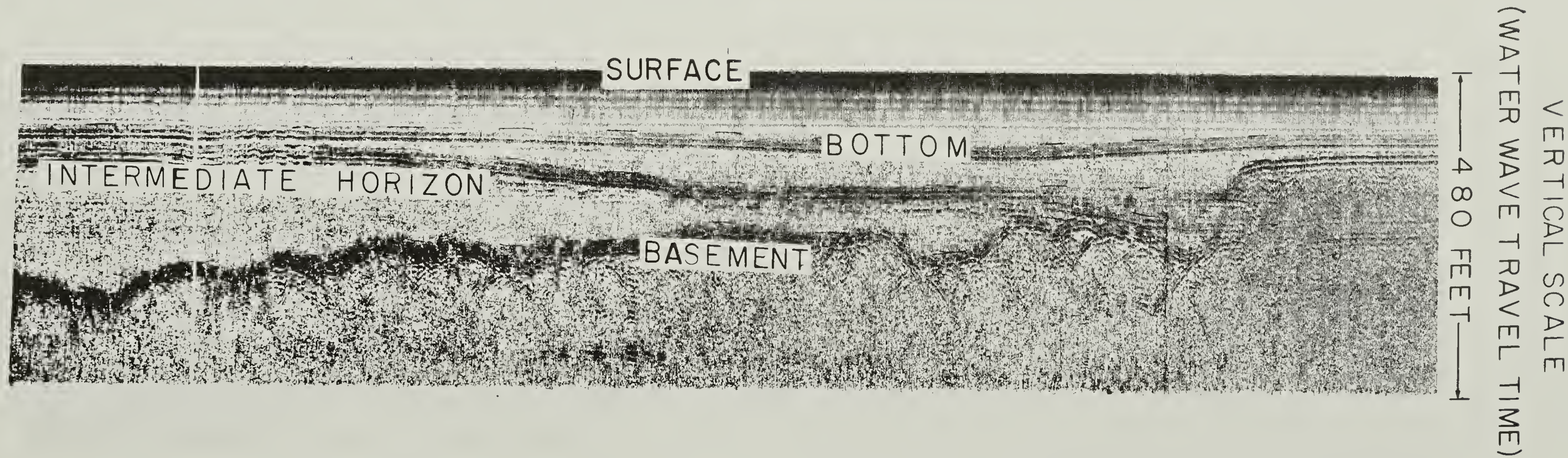
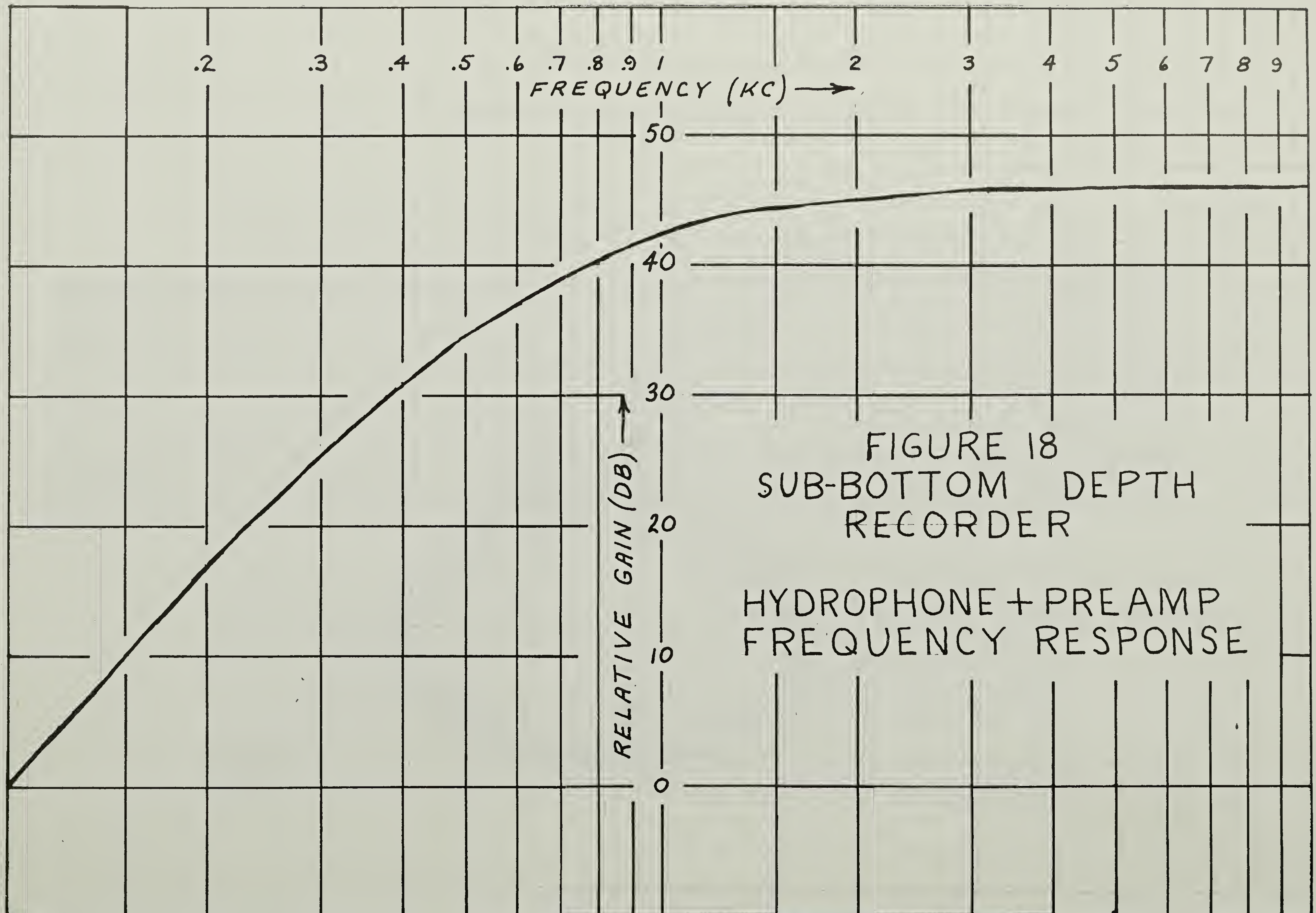


FIGURE 16 LONG ISLAND SOUND NEAR FLAT NECK POINT, CONN.

This record shows good penetration of the sound energy to basement rock and indicates clearly the rather rough topography of the basement. An intermediate layer is clearly visible between the water bottom and basement rock.

FIGURE 17 SDR ELECTRODE ASSEMBLY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5
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7
8
9
FREQUENCY (KC)
50
40
30
20
10
0
RELATIVE GAIN (DB)
FIGURE 18
SUB-BOTTOM DEPTH
RECORDER
HYDROPHONE + PREAMP
FREQUENCY RESPONSE